10

Grazing Impacts on Mountain Meadows of the Peninsular Ranges in *La Frontera*

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Different fire and grazing management practices in the United States and Mexico, especially in the past century, are manifested in the ecosystems of the Peninsular Ranges spanning the California/Baja California boundary. The San Jacinto/Santa Rosa Mountains of California and the Sierra San Pedro Mártir of Baja California are, respectively, the northern and southern termini of the Peninsular Ranges. Each of these topographically similar mountains (> 3,000 m in elevation) consists of an approximately 100 x 30 km block of granitic and older metamorphic rocks uplifted with the Peninsular Ranges batholith since the Mesozoic (California. Division of Mines and Geology 1966; Gastil et al. 1975). At present, they share a transitional climate with both Mediterranean and tropical influences.

On the Mexican side, the summer grazing of livestock in the meadows of the Sierra San Pedro Mártir (SSPM) has been relatively heavy during most of this century, especially from the 1910s to the 1970s, when large numbers of sheep were grazed (Minnich et al. 1997). In contrast, during the past 60 years on the U.S. side, the intensity of livestock grazing in the San Jacinto Mountains (SJM) has been moderate or absent (Barbour et al. 1991). The disparate development of ecosystems across the U.S./Mexico boundary constitutes a natural experiment that may help elucidate how ecosystems diverge as a result of differences in land management.

Although livestock grazing is not permitted in Mexican national parks, summer grazing in the meadows has been a traditional and enduring economic activity in the SSPM since the establishment of Misión San Pedro Mártir in the late eighteenth century. Recently, Minnich et al. (1997) have proposed the SSPM as a biosphere reserve under United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) Man and Biosphere Program. However, even under this program grazing and other economic activities may be permitted in the SSPM.

Grazing and release from grazing may alter the composition and diversity of species in herba-

ceous communities (Milchunas et al. 1988); both are important components of stable ecosystems (Pimm 1984). Interest in the effects of grazing on the composition and diversity of species is twofold. First, the basis of grazing management in most pastures is to induce favorable changes in the composition of species (Daget and Poissonet 1969; Joyce 1989; Lauenroth and Laycock 1989); and second, high species diversity in plant communities is thought to confer resistance to and allow faster recovery from disturbance (Tilman and Downing 1996). The response of dominant species to grazing is important, moreover, because dominants are good indicators of the value and carrying capacity of the grazing resource (Milchunas and Lauenroth 1993; Poissonet et al. 1988). The aims of this study were to evaluate the impact of grazing by measuring soil properties and determining the composition, distribution, abundance, and diversity of species in the plant communities of wet and dry meadows in the forested areas of the SSPM and the SJM.

Study Areas

Twenty-two high-elevation meadow sites were studied during 1990 and 1991 in the SSPM and the SJM. On the Mexican side, meadows were studied in the Parque Nacional San Pedro Mártir at Vallecitos, La Grulla, La Encantada, and Rancho Nuevo; and on the California side, at Mount San Jacinto State Park, the University of California's James Reserve, Garner Valley, Fobes Ranch, and Round Valley (table 10.1). The wet meadows, which are surrounded by conifer forest, are in low areas, associated either with streams or shallow water tables. The dry meadows lie in the transition between wet meadows and the surrounding forest.

The topography was similar at all sites: slopes were slight or nil, and there was no dis-

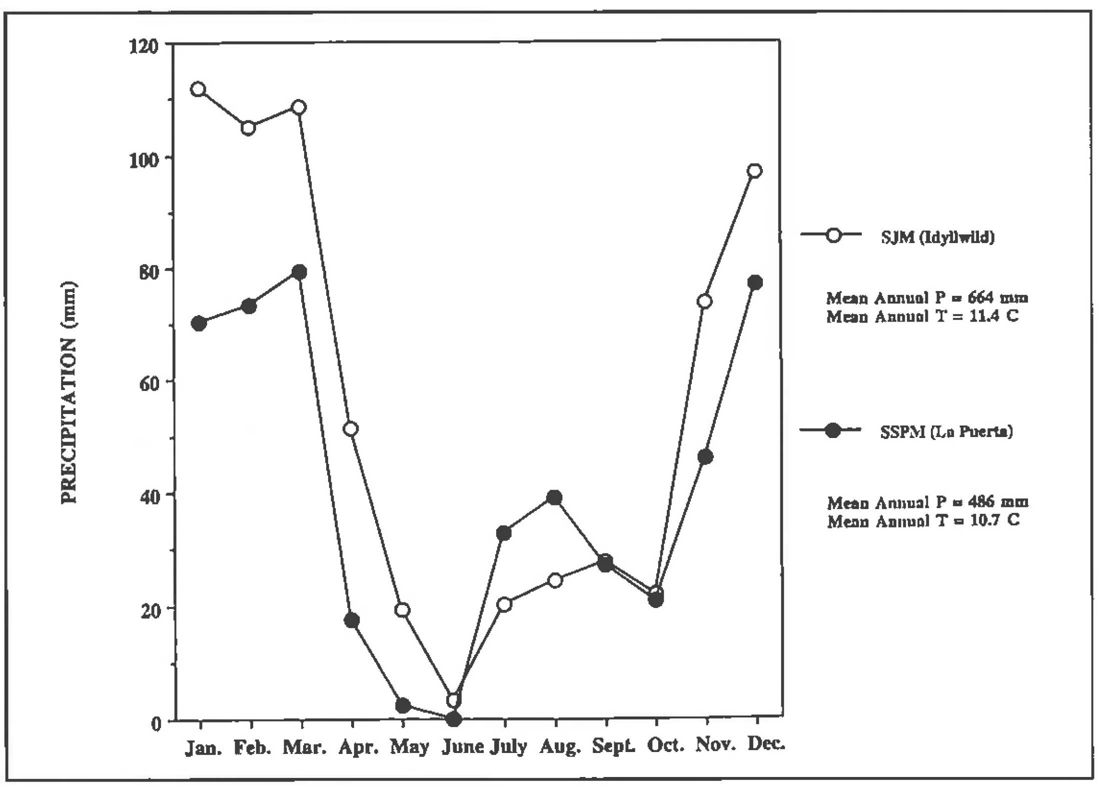

FIG. 10.1

Average annual and monthly precipitation in the San Jacinto Mountains (SJM) and the Sierra San Pedro Mártir (SSPM).

			Sierra San Pedro Mártir															San Jacinto Mountains						
Site			VA	VA	VA	VA	RN	LG	LG	LG	LG	LG	LG	LG	LE	LE	LE	SJ	JR	GV	GV	FR	FR	RV
Wet/Dry Meadow			W	D	D	D	W	D	D	D	D	W	D	D	D	D	D	W	W	D	D	D	D	W
Grazing Intensity			H	H	H	H	H	H	H	M	L	L	M	M	H	H	M	N	N	M	L	M	M	N
Species	Distribution	Grazing Value																						
Abronia villosa	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Achillea millefolium ssp. *californica*	NAm		—	—	1	—	—	—	—	—	—	—	—	3	1	—	13	—	—	—	—	1	—	—
Achillea millefolium ssp. *lanulosa*	NAm	L	1	1	4	3	34	15	—	1	—	—	38	—	25	3	—	10	—	—	—	—	—	—
Achnatherum coronatum	CAFP	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Achnatherum diegoense	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
Achnatherum nelsonii	NAm	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Agrostis exarata	NAm	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Agrostis scabra	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Allionia incarnata	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Anoda cristata	EXO		—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aristida adscensionis	Am		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	1	—	—	—	—
Aristida glauca	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	27	1	—	—	—	—
Artemisia dracunculus	Nam		—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1	1	—	—	—	—	—
Artemisia tridentata	Nam		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	—
Aster bernardinus	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	—	—
Aster occidentalis ssp. *delectabilis*	CAFP	L	32	—	—	1	—	—	—	—	—	1	—	15	—	—	16	—	—	—	—	—	—	—
Astragalus circumdatus	PRa	L	1	1	—	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Astragalus palmeri	CAFP		—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Atriplex sp.	—		—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Blepharoneuron tricholepis	NAm		—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bouteloua sp.	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10	—	—	—
Bromus mollis	EXO	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Bromus tectorum	EXO	L	1	—	—	—	1	1	—	16	—	—	—	—	—	—	—	—	1	—	41	1	56	—
Calochortus splendens	CAFP	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Calyptridium monandrum	CAFP		—	1	1	—	1	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—
Carex douglasii	NAm	S	—	—	27	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex hassei	Nam		1	—	—	—	2	42	—	1	—	—	—	3	2	—	13	—	—	—	—	—	—	—
Carex nebrascensis	Nam	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	94
Carex occidentalis	Nam		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	87	—	—	—	—	—	—
Carex praegracilis	Am		—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Carex subfusca	Nam		—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1
Carex sp.	—		—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	50	—	—
Chaenactis glabriuscula	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	—
Chamaesyce fendleri	Nam		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Chrysopsis villosa	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Cirsium scariosum	Nam		1	1	1	—	1	1	1	—	—	—	1	—	—	1	7	—	—	—	—	—	—	—
Cryptantha intermedia	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—
Dodecatheon alpinum	Nam	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12
Eleocharis paucillora	Am		—	—	—	—	—	1	—	—	—	84	—	—	—	—	—	—	—	—	—	—	—	—
Elymus elymoides	NAm	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Elymus sp.	—	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Epilobium lactiflorum	EXO		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Epilobium oregonense	Nam		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Eragrostis cilianensis	EXO		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Eremocarya sp.	CAFP		—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—

TABLE 10.1

Frequency (4 m transect, 100 points), distribution, and grazing value of species and characteristics of study sites in wet and dry meadows of the Sierra San Pedro Mártir and San Jacinto Mountains.

			Sierra San Pedro Mártir															San Jacinto Mountains						
Site			VA	VA	VA	VA	RN	LG	LG	LG	LG	LG	LG	LG	LE	LE	LE	SJ	JR	GV	GV	FR	FR	RV
Wet/Dry Meadow			W	D	D	D	W	D	D	D	D	W	D	D	D	D	D	W	W	D	D	D	D	W
Grazing Intensity			H	H	H	H	H	H	H	M	L	L	M	M	H	H	M	N	N	M	L	M	M	N
Species	Distribution	Grazing Value																						
Eriastrum sapphirinum ssp. *gymnocephalum*	PRa		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Erigeron foliosus	CAFP	L	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eriogonum davidsonii	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Eriogonum hastatum	PRa		—	—	—	—	—	—	—	—	—	—	—	—	23	—	—	—	—	—	—	—	—	—
Eriogonum cf. *lanatum*	—		—	—	—	—	1	—	1	4	3	—	—	—	—	—	—	—	—	—	—	—	—	—
Eriogonum wrightii ssp. *oresbium*	PRa	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Eriogonum sp.	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Erodium cicutarium	EXO	L	—	—	—	—	—	1	1	1	—	—	—	—	1	—	—	—	—	1	14	1	6	—
Erysimum capitatum	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Euphorbia misera	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Euphorbia palmeri	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Gilia ochroleuca	CAFP		—	4	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gnaphalium palustre	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	—	—	—	1
Gutierrezia sarothrae	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Hemizonia mohavensis	CAFP	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Hordeum brachyantherum	NAm	S	1	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hordeum jubatum	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11	—	—	—	—	—
Hulsea mexicana	PRa		—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	—	—	—	—	—
Ipomopsis effusa	PRa		—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ivesia argyrocoma	PRa		—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Juncus mexicanus	NAm	L	1	—	—	16	17	1	—	—	—	96	—	50	—	—	33	—	—	1	—	73	—	—
Koeleria macrantha	EXO	P	1	—	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lepidium montanum	NAm	L	1	2	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lesquerella peninsularis	SPM		—	—	—	—	—	—	1	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Lessingia filaginifolia	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Lessingia glandulifera	PRa		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
Linanthus ciliatus	CAFP	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Linanthus lemmonii	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	1	—
Linanthus melingii	Pra		1	7	1	1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lotus strigosus	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Lupinus andersonii ssp. *sublinearis*	PRa	S	—	—	—	—	—	—	—	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—
Lupinus bicolor	CAFP	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Lupinus formosus	CAFP		—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	18	—
Mimulus primuloides	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1

Sites: FR = Fobes Ranch, GV = Garner Valley, JR = James Reserve, LE = La Encantada, LG = La Grulla, RN = Rancho Nuevo, RV = Round Valley, SJ = Mount San Jacinto State Park, VA = Vallecitos.

Meadows: D = Dry Meadow, W = Wet Meadow.

Grazing Intensity (all grazing by domestic animals was by cattle): H = High, L = Low, M = Medium, N = Not Grazed.

Distribution (from Wiggins [1980] and Hickman [1993]: Am = Americas, CAFP = California Floristic Province, EXO = exotic, NAm = North America, PRa = Peninsular Ranges, SPM = Sierra San Pedro Mártir.

Grazing Value: L = low, P = primary, S = secondary (USDA 1969).

TABLE 10.1 *CONTINUED*

			Sierra San Pedro Mártir															San Jacinto Mountains						
Site			VA	VA	VA	VA	RN	LG	LG	LG	LG	LG	LG	LG	LE	LE	LE	SJ	JR	GV	GV	FR	FR	RV
Wet/Dry Meadow			W	D	D	D	W	D	D	D	D	W	D	D	D	D	D	W	W	D	D	D	D	W
Grazing Intensity			H	H	H	H	H	H	H	M	L	L	M	M	H	H	M	N	N	M	L	M	M	N
Species	Distribution	Grazing Value																						
Mirabilis pumila	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Muhlenbergia asperifolia	Am	L	—	—	—	—	9	43	—	—	—	—	1	—	2	45	18	—	—	—	—	—	—	—
Muhlenbergia filiformis	NAm	L	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Muhlenbergia richardsonis	NAm	S	1	14	—	1	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
Nassella cernua	CAFP	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Nassella lepida	CAFP	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	32	—	—	—	—
Oenothera californica	NAm	L	—	—	—	—	—	—	1	—	1	—	2	—	—	—	—	—	—	—	—	—	—	—
Oenothera hookeri var. *grisea*	CAFP		—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Ophiocephalus angustifolius	SPM		—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Perideridia parishii	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Phleum alpinum	EXO	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Phlox austromontana	NAm	L	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Plantago linearis ssp. *mexicana*	NAm		1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Plantago subnuda	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Plantago sp.	—		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Poa bolanderi	NAm		—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa pratensis	NAm	P	—	—	1	—	4	1	—	1	—	—	17	69	—	—	49	—	—	—	—	—	—	1
Portulaca oleracea	EXO		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Potentilla wheeleri	PRa	L	3	1	48	42	2	36	1	—	—	—	1	2	7	6	19	10	—	—	—	—	—	—
Ranunculus alismifolius	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Rumex salicifolius	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Sidalcea malviflora ssp. *sparsiflora*	CAFP	L	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—
Sisymbrium altissimum	EXO	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Sisymbrium irio	EXO		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Solidago californica	CAFP		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15	—	—
Sphaeralcea ambigua?	NAm	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Sporobolus contractus	NAm		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
Sporobolus cryptandrus	NAm	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Taraxacum officinale	EXO	L	1	—	—	1	1	10	—	—	—	—	—	4	1	1	7	1	—	—	—	—	—	—
Trifolium monanthum	NAm	P	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	—	—	—	—	—	—
Trifolium variegatum	NAm	P	—	—	—	—	1	7	—	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Trifolium wigginsii	SPM	P	2	1	16	1	7	—	—	—	—	—	6	26	—	—	21	—	—	—	—	—	—	—
Trifolium wormskjoldii	NAm	P	—	—	—	—	—	—	—	—	—	—	—	48	—	—	—	—	—	—	—	—	—	—
Veronica peregrina	Am	L	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Vulpia myuros	EXO	L	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—
Vulpia octoflora	EXO		—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—

Sites: FR = Fobes Ranch, GV = Garner Valley, JR = James Reserve, LE = La Encantada, LG = La Grulla, RN = Rancho Nuevo, RV = Round Valley, SJ = Mount San Jacinto State Park, VA = Vallecitos.

Meadows: D = Dry Meadow, W = Wet Meadow.

Grazing Intensity (all grazing by domestic animals was by cattle): H = High, L = Low, M = Medium, N = Not Grazed.

Distribution (from Wiggins [1980] and Hickman [1993]: Am = Americas, CAFP = California Floristic Province, EXO = exotic, NAm = North America, PRa = Peninsular Ranges, SPM = Sierra San Pedro Mártir.

Grazing Value: L = low, P = primary, S = secondary (USDA 1969).

cernible direction of exposure. Elevations varied on the Mexican side from 2,080 m at La Grulla to 2,420 m at Vallecitos, while on the U.S. side they ranged from 1,680 m at the James Reserve to 2,590 m at Mount San Jacinto State Park.

The Peninsular Ranges lie in the transition between the Mediterranean climatic regime of wet winters and dry summers along the Pacific coast of California and Baja California, and the tropical regime of dry winters and wet summers of the Mexican mainland. The SSPM is the southernmost outpost of North America's Mediterranean climate (Minnich and Franco-Vizcaíno 1997). The distribution of annual precipitation on both mountains is bimodal, with winter precipitation dominated by frontal storms and summer precipitation mostly from thunderstorms associated with the North American monsoon (figure 10.1). The SSPM is more arid than the SJM, receiving only ca. 75% of the mean annual precipitation of the SJM. Moreover, 82% of the annual precipitation in the SJM falls from November through April, and 18% from May through October, while these proportions are 75% and 25% in the SSPM. This aridity is alleviated somewhat in that precipitation is slightly higher in the SSPM during the summer monsoon (99 mm, or 20% of the total) when plants are growing, while summer precipitation in the SJM is 72 mm, or 10% of the total. On both mountains, winters are cold and summers are warm, with similar temperature regimes at similar sites.

Methods

At each meadow, plant communities associated with wet and dry zones were sampled randomly. Floristic composition was determined as in Daget and Godron (1982) by recording all of the plant species in a representative, homogeneous surface (the optimal area of which was estimated to be 16 m^2), in order of increasing surface area: $1/64$, $1/32$, $1/16$, $1/8$, $1/2$, 1, 2, 4, 8 and 16 m^2. At each stage, species appearing for the first time were noted and environmental variables, such as elevation, relief, apparent wetness or dryness, and type of soil, were recorded.

One soil sample was taken from both the A and B horizons at each study site to a depth of 30 cm (or to the depth of the water table). Soil samples were air dried prior to sieving, and the < 2 mm fraction was analyzed using standard methods (Page et al. 1982). Organic carbon and total nitrogen were estimated by the Walkley-Black and Kjeldahl procedures, respectively. Inorganic nitrogen was extracted with 1M potassium chloride, and nitrate and ammonium were measured by automated colorimetry. Soils were saturated with deionized water, and salinity (EC) as well as pH were measured in the saturation extracts. Concentrations of major

Meadow Type	No. Sites	Soil pH	Soil Organic Matter (%)	Soil Total Nitrogen (mg/kg)	Soil C:N Ratio	Soil Total Phosphorus (mg/kg)	Clay(%)	Species Richness
Sierra San Pedro Mártir								
Dry Meadow	12	6.6±0.7*	2.3±2.0	1440±1060	9±2**	590±530#	9±6	11±3*
Wet Meadow	3	5.9±0.7	9.4±10.1	3080±1150#	15±11	750±610	13±4*	13±6
San Jacinto Mountains								
Dry Meadow	4	5.9±0.2*	2.4±1.3	1030±930	20±11**	290±170#	9±3	15±3*
Wet Meadow	3	5.6±0.1	12.5±15.9	1250±680#	46±39	640±540	5±2*	12±3

Values followed by #, *, ** are significantly different at P < 0.10, < 0.05, < 0.01, respectively.

TABLE 10.2

Soil properties of the A horizon and species richness in mountain meadows of the Sierra San Pedro Mártir and the San Jacinto Mountains. (Values are means ±1 standard deviation.)

TABLE 10.3

Concentrations of extractable inorganic nitrogen, and phosphorus and major cations in aqueous extracts from mountain meadow soils in the Sierra San Pedro Mártir and the San Jacinto Mountains. (Values are means ±1 standard deviation.)

Meadow Type	No. of Sites	Extractable Nitrate + Ammonium (mg/kg)	Saturation Extract mg/L				
			Phosphate	Potassium	Magnesium	Calcium	Sodium
Sierra San Pedro Mártir							
Dry Meadow	12	9.3±4.6*	1.1±0.9#	5.9±5.6	0.5±0.4	2.9±2	2.5±3.7
Wet Meadow	3	14.9±12.0	1.8±0.9	4.8±1.8	0.9±0.3	2.6±0.1	1.7±2.8
San Jacinto Mountains							
Dry Meadow	4	20.3±16.3*	3.6±4.3#	7.3±7.8	0.7±0.7	3.5±3.8	0.4±0.1
Wet Meadow	3	18.5±10.7	2.0±0.6	7.4±3.3	0.5±0.3	2.0±1.3	0.5±0.1

Values followed by #, * are significantly different at P < 0.10 and < 0.05, respectively.

tions and boron were measured in a subsample of the saturation extract by plasma spec-ometry (DCP). Soil texture was determined by the hydrometer method.

Plant abundance and ground cover were estimated by the line-intercept method (Daget ıd Poissonet 1969); species were recorded at 100 points, each separated by 4 cm, along a 4-m line parallel to the soil surface (table 10.1). By convention, each species is taken into account only once per point. This method evaluates the frequency of each species encountered, so that its specific contribution can be calculated as a percentage. At the same time, the vertical structure of the vegetation was measured by recording the height of each plant along the 100 points. The relative grazing value of each species was assigned after consulting the *Range Environmental Analysis Handbook for the California Region* (United States. Department of Agriculture 1969). Soil properties of the A horizon and species richness and diversity were compared between the two mountains, separating dry from wet meadows, by using the StatView 4.0 program (ANOVA). The line-intercept data for the 22 sites were used to calculate species frequencies by using the SPSS program.

Results

Soils at the SSPM sites were slightly acid to neutral; whereas, those at the SJM were slightly to moderately acid (table 10.2). Soils in the dry meadows of the SJM were significantly more acid than those of the SSPM. None were saline, and electrical conductivities were generally < 0.5 dS/m. Soils at all of the sites developed mostly on alluvium from granitic rocks and consequently are coarse textured. Soils at the SSPM sites were mostly sandy loams but ranged from sands in two dry meadows to sandy clay loams in two wet meadows. Most soils at the SJM sites were sandy loams but ranged from sand in one dry meadow to loamy sands in both dry and wet meadows. Clay contents in soils of SSPM wet meadows were significantly higher than those of the SJM wet meadows.

In both mountains, soils in wet meadows had higher organic matter contents than soils in dry meadows. There were, however, no significant differences in organic matter content between the mountains (table 10.2). Concentrations of total soil nitrogen were generally high, but the SSPM wet meadows tended to have higher nitrogen concentrations than the SJM wet meadows ($P < 0.1$). Carbon to nitrogen ratios were low only in the SSPM dry meadows but were significantly higher in the SJM dry meadows. There was a trend ($P < 0.1$) towards higher

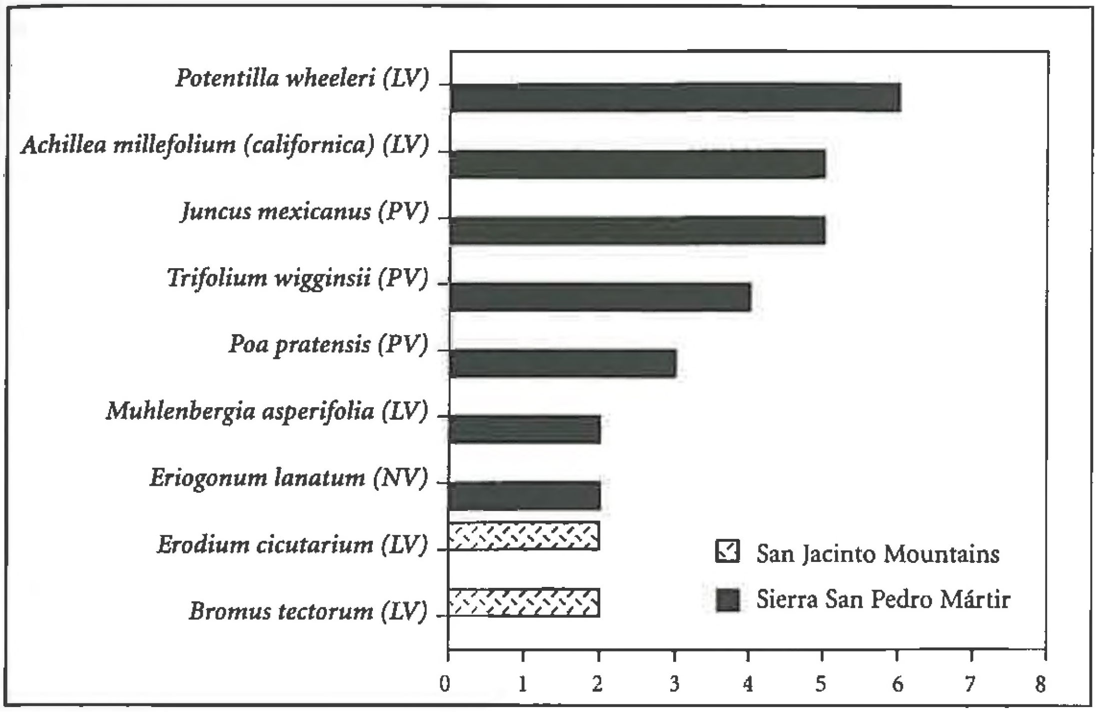

FIG. 10.2

Number of sites dominated by the most widely distributed species in the meadows in the San Jacinto Mountains and the Sierra San Pedro Mártir. NV = no grazing value; LV = low grazing value; PV = primary grazing value.

total soil phosphorus in the dry meadows of the SSPM than the SJM. While the mean concentrations of nitrogen and phosphorus were similar to those reported for the soils supporting Mediterranean-type shrublands in California and the Mediterranean basin, several meadows had concentrations of phosphorus as low (< ~200 mg/kg) as those of the relatively infertile Australian heath (Christensen 1994).

Most soils had low concentrations of extractable nitrogen, and of phosphorus, potassium, magnesium, and calcium in the saturation extract (table 10.3). The concentrations of major cations in the aqueous extract were generally lower than the minima reported for 30 soil series from agricultural areas of California (Bradford et al. 1971). With the exception of slightly higher soil pH, the properties of meadow soils reported here were generally similar to those reported for a pine-forest site in the SJM by Hanawalt and Whittaker (1976, 1977a).

A total of 115 taxa were found at the 22 sites (table 10.1). Of these, 54 (47%) occurred in the SSPM and 78 (68%) in the SJM, with species richness being significantly higher in dry meadows in the SJM than in the SSPM (table 10.2). Only 16 taxa occurred on both mountains. Of the species found in the SSPM, 11 were grasses (20%) and seven were legumes (13%), while in the SJM 23 species were grasses (29%) and four were legumes (5%). Overall, 30 species (26%) were found in three or more sites, 11 (9%) were found in six or more sites, and only one (0.8%) was found in 12 or more sites. In the SSPM, 26 species (48%) were found in three or more sites, nine (17%) were found in six or more sites, and one (1.8%) was found in 12 or more sites. In the SJM, only four species (5%) were found in three or more sites, and none occurred at six or more sites. These results demonstrate that, although a larger number of species occur in the SJM, they tend to be of low abundance and restricted distribution. On the other hand, there are fewer species in the SSPM, but they tend to be more abundant and more widely distributed.

Dominant species were defined as those two or three species having the highest frequencies

at each site. In this study 34 species were found to be among the two or three dominant species in at least one site. Of these, nine are grasses (of which seven have some grazing value), six are legumes (five having grazing value), and of the remaining 19 forbs, nine have some grazing value. At the SSPM, 21 species were dominant, and of these yarrow (*Achillea millefolium*), June grass (*Poa pratensis*), *Juncus mexicanus*, *Potentilla wheeleri*, and *Trifolium wigginsii* were widely distributed (figure 10.2). At the SJM 17 species are dominant and of these cheat grass (*Bromus tectorum*) and filaree (*Erodium cicutarium*) were dominant at two sites, while the rest were dominant at only one site each.

In terms of the quality of the grazing resource, rangelands in both mountains appear to be degraded. Of the 115 taxa identified in the meadow sites, 52 are classified as having some grazing value (table 10.1). Of these, 31 species are classified as having low value, nine of secondary value, and 12 of primary value. Of the nine dominant species that appeared in more than two sites, seven were found in the SSPM and two in the SJM (figure 10.2). Three species of primary value and three of low value have wide distribution in the SSPM, but both of the dominants found at more than one site in the SJM are of low value. This demonstrates that the grazing value of the SSPM rangelands is superior to that of the SJM rangelands. It appears to us that moderate grazing intensity in the SSPM may help maintain the value of mountain meadows for livestock.

Discussion

The soils of dry meadows in the SSPM had significantly higher pH and lower C:N ratios than those of SJM (table 10.2). This is consistent with the higher rainfall amounts in the SJM, since more humid regions tend to have more acid soils and wider C:N ratios. The contents of organic matter and of total nitrogen and phosphorus indicate that soils in the majority of meadows are fertile, although a few individual meadows are low in nitrogen and phosphorus (~200 mg/kg) and have high C:N ratios (> 20), as indicated by the large standard deviations of these variables. Depletion of soil nutrients, especially phosphorus, by livestock is not addressed here because in the majority of the meadows recurrent flooding, usually during El Niño events, results in deposition of organic matter and soil from surrounding uplands.

In contrast to the generally high contents of total soil nitrogen, the concentrations of extractable inorganic nitrogen were low, and significantly higher in the SJM than in the SSPM dry meadows (table 10.3). This was likely not a meaningful comparison because soil samples were air dried in the field prior to transport to the laboratory and were collected over two growing seasons. Consequently, the higher nitrogen concentrations in soils with higher C:N ratios may more closely reflect the flush of nitrogen made available during the drying process. Nonetheless, the availability of inorganic nitrogen appears to be limiting in these meadow soils. This is likely exacerbated in soils having C:N ratios higher than ~20 because any inorganic nitrogen made available by the decomposition of organic matter is more readily scavenged by soil microbes than by plant roots.

Our results suggest that these coarse-textured soils have low nutrient supplying capacities, especially of cations, and that the majority of nutrients are held by organic matter replenished by runoff events. It is possible that the nutrients available to plants are low because the decomposition of organic matter and cattle excreta is slow due to aridity in summer and cold in winter. Plants in these meadows are thus likely adapted to very low concentrations of multiple soil nutrients. Common strategies of plants that tolerate nutrient-poor sites, where

water and light are not limiting, are increased leaf longevity and relatively slow growth rates (Chapin 1980). These strategies, however, may be complicated by intense livestock grazing.

The Californian Floristic Province (CAFP), which is characterized by great climatic variability and geographic discontinuities such as islands and mountains, has notable floristic diversity with some 4,437 species of vascular plants (Raven 1977; Webster, this volume). Of the 115 taxa reported in this study, 39 (34%) are endemic to the CAFP (table 10.1). Of these, 14 are endemic to the Peninsular Ranges (three in the SSPM) and five are listed as having a high grazing value index. A total of 14 nonnative species was recorded, of which eight were found only in the SJM, three only in the SSPM, and three in both mountains. While both cheat grass and filaree are widespread in both mountains, they are dominants only in the SJM meadows. The distribution and dominance of nonnative species is consistent with the relative isolation of the SSPM.

The presence, absence, and abundance of species in a plant community are the result of numerous biotic and abiotic factors. Livestock grazing removes organs from individual plants and alters community structure. Plant reaction to grazing pressure depends on the ability to compensate for the loss of organs, while maintaining competitive relationships in the canopy. Grazing appears to select for low, prostrate growth forms and can lead to the transformation of grasslands to shrublands and of perennial grasslands to annual grasslands (Milchunas and Lauenroth 1993).

Some of the above generalizations were confirmed by our studies in the meadows of the SJM and the SSPM. For example, in the SSPM, heavily grazed dry to moderately wet meadows are dominated by low prostrate forms such as *Achillea millefolium*, *Aster occidentalis*, *Potentilla wheeleri* and *Trifolium wigginsii*. In moderately grazed somewhat dry to moderately wet meadows, the dominants are perennial grasses and their associates: *Poa pratensis*, *Muhlenbergia asperifolia* and *Juncus mexicanus*, in conjunction with *Achillea millefolium* and *Trifolium wigginsii*. In the ungrazed wet meadows in the SJM are found tall perennial grasses and grass-like forms such as foxtail barley (*Hordeum jubatum*), Nebraska sedge (*Carex nebrascensis*) and *Carex occidentalis*; the dominants in this same type of locality in the SSPM are *Juncus mexicanus* and few-flowered spikerush (*Eleocharis pauciflora*). That livestock grazing can transform perennial grasslands into annual grasslands is confirmed by our observations of dry meadows having moderate grazing in both mountains because they tend to be dominated by annuals such as *Bromus tectorum* and *Erodium cicutarium*.

With regard to the livestock grazing value of meadows, sites having moderate grazing and intermediate moisture gradients have the highest value, especially if they are dominated by species such as *Poa pratensis* and *Muhlenbergia asperifolia*. We believe that reducing the grazing of degraded meadows in the SSPM from high to moderate intensities would increase species diversity and improve the grazing value and abundance of grasses and legumes in the meadows (Collins et al. 1998; Daget and Poissonet 1971).

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